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Mission Highlights

STS-77

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Astronauts complete 'grand slam'

After successfully demonstrating a second technological marvel and completing a record fourth rendezvous on the same flight, the crew of the Space Shuttle *Endeavour* glided to Earth after a 10-day mission featuring 21 hours of precise formation flying with the Spartan 207 and PAMS-STU satellites.

The fourth rendezvous with a trash can-sized Satellite Test Unit took place on Memorial Day as scientists, testing whether they could keep a satellite properly aligned using weights and magnets rather than propellant, were rewarded with a good laser lock.

Four hours of precise laser measurements, that had not been achieved on the first two rendezvous with PAMS-STU, gave the scientists a third data source to add to the radar and video data collected on all three approaches. The laser imaging system was the most accurate data source for validating the aerodynamic stabilization process.

The findings were important for researchers seeking answers to the space age-old problem of how to keep a satellite in place without heavy, expensive and hazardous propellants.

As *Endeavour* held station with PAMS-STU, Commander John Casper spoke with fellow American Shannon Lucid, who was completing her 65th day on orbit aboard Mir. She congratulated the STS-77 astronauts on the success of their mission, invited them to tea and gave them some good-natured ribbing about the duration of their flight:

"It hardly seems worth the effort to go up in space for only 10 days," she chided.

The Inflatable Antenna Experiment nears completion of its inflation process over California's Pacific Coast near Santa Barbara and Point Conception.

Space Shuttle *Endeavour*

May 19-29, 1996

Commander: John H. Casper

Pilot: Curtis L. Brown, Jr.

Mission Specialists: Andrew S. W. Thomas
Daniel W. Bursch
Mario Runco, Jr.
Marc Garneau

Earlier in the flight, the crew had successfully deployed the Spartan free-flyer, which in turn deployed the Inflatable Antenna Experiment, the first inflatable structure in space since the Echo balloons of the 1960s. Reducing the size and weight of spacecraft components again was the goal.

Inflatable equipment could be important to future spacecraft because it costs less, takes up less space and is potentially more reliable during deployment in space.

Throughout the flight, the crew tended experiments in the commercial Spacehab module that ranged from studies of how aquatic organisms developed in the Aquatic Research Facility to growing large crystals important to electronic devices in the Commercial Float Zone Facility.

Mission Events

Liftoff of the *Endeavour* occured at 5:30 a.m. CST, on May 19, 1996, following a flawless countdown. The STS-77 crew immediately deployed the shuttle's KU-band radio antenna and began the process of turning on a host of materials and life science experiments in the Spacehab, which was designed to increase the volume of workspace available to orbiting shuttle crews.

Astronaut Runco began experiements with the Aquatic Research Facility (ARF), a type of orbital aquarium on *Endeavour's* lower deck. The facility studied the early development in weightlessness of sea urchins, mussels and starfish. The studies provided clues to how humans may develop in weightlessness.

Other experiments activated aboard *Endeavour* included an investigation called GANE that uses global Positioning System satellites to determine a spacecraft's orientation; an experiment called BETSCE that tests a new, supercold refrigeration system that needs no moving parts and could be used on orbiting astronomical instruments; and a Commercial Float Zone furnace, that produced large crystals for use in semiconductors and infrared sensors.

The Spartan satellite was released at 6:29 CST May 20, for its 24-hour free flight away from *Endeavour* to test new inflatable antenna technology. At 8:38 a.m. CST, the Inflatable Antenna Experiment inflated to its full 92-foot length, supporting a 50-foot diameter dish. IAE was jettisoned about 90 minutes later, according to plan.

On May 21, at 9:53 a.m. CST, the STS-77 crew retrieved the Spartan satellite and reberthed it in the payload bay. Meanwhile, the crew continued work with the variety of experiments in the Spacehab module, including some troubleshooting of the Fluid Generic Bioprocessing Apparatus, a soft-drink dispenser designed to investigate the mixture of fluid and gas in weightlessness.

The Passive Aerodynamically Stabilized Magnetically Damped Satellite (PAMS) was deployed from a canister in the rear of the shuttle payload bay at 4:18 a.m. CST May 22. It drifted away from the orbiter in a rotating, unstable attitude by design to evaluate how quickly and effectively the spacecraft could stabilize itself using the aerodynamic stabilization method rather than thrusters.

Astronaut Mario Runco uses a large format camera during station keeping operations with the PAMS/STU satellite.

Halfway through the STS-77 mission, crew members were spending the bulk of their time tending a host of experiments ranging from biological studies of sea creatures in weightlessness to experiments in crystal growth and materials processing. These activities included monitoring the Space Experiment Facility (SEF) and Commercial Float Zone Furnace (CFZF) and changing samples and videotapes and taste testing soda in the Fluids Generic Bioprocessing Apparatus (FGBA). The crew also conducted a health check of the ARF.

On May 25, the *Endeavour* closed in for another rendezvous with the PAMS-STU. Casper and Brown pulled the shuttle to within 2,000 feet at about the same time, where the astronauts began to take attitude measurements of the satellite's stability by reflecting laser light on it. A commanding problem was detected with the SEF in the Spacehab module and Astronaut Thomas began troubleshooting procedures relayed from the Payload Operations Control Center. Officials determined that the device had failed. SEF was one of several materials processing and crystal growth experiments that made up the flight's science investigations.

On May 26, Astronauts Thomas and Bursch fixed a faulty cooling system in the Spacehab module by switching a valve in the cooling water loop to a backup motor. Then on May 27, the crew made the third rendezvous with the PAMS-STU. While the orbiter's payload bay was pointed carefully toward the satellite, payload controllers at Goddard Space Flight Center sent commands to an on-board Attitude Measurement System (AMS) to try to calculate the satellite's attitude to within a tenth of a degree of accuracy. The mechanism, which swivels the AMS to the proper position, was slowly moved through various positions to lock on to the satellite and gather attitude data. The technology demonstration experiment has proven the concept of propellent-free satellite stabilization.

The *Endeavour* glided home at 6:09 a.m. CST May 29, to Kennedy Space Center wrapping up a 10-day, 4.1 million mile mission devoted to technology research.

Payload Descriptions

SPARTAN 207/IAE: The STS-77 crew deployed and tested the Inflatable Antenna Experiment (IAE) to validate the deployment (inflation) and performance of a large inflatable antenna. The antenna was developed by L'Garde Inc., of Tustin, CA, a small

Astronaut Daniel Bursch works out on the bicycle ergometer.

Canadian Astronaut Marc Garneau joins Pilot Curtis Brown in checking out the audio control system for Spacehab.

aerospace business, and JPL, under NASA's In-Space Technology Experiments Program.

Inflatable structures have the potential to deploy much more reliably than conventional mechanical systems used for deploying rigid structures. In addition, the small package size of the inflatable components allows very large structures to be deployed in space with a single small launch vehicle. Inflatable systems cannot be evaluated on Earth due to the effects of gravity and atmospheric pressure on the balloon structure.

The Spartan carrier also tested a Solid-State Recorder using flash memory, developed under a Small Business Innovative Research contract between Goddard and SEAKR Engineering, Inc. of Englewood, CO. Some of the electronics boxes on the Spartan carrier implemented a Parylene coating process that allows the use of commercial plastic integrated circuits on-orbit.

The Spartan project was managed by NASA's Goddard Space Flight Center, Greenbelt, MD, for the Office of Space Science, Washington, DC. IAE is sponsored by NASA's Office of Space Access and Technology, Washington, D.C.

SPACEHAB-4

The Advanced Separation Process for Organic Materials (ADSEP) sought to enhance separation technologies for medical products. Separation, purification and classification of cells are limiting factors in biomedical research and pharmaceutical drug development. Advanced separation technology, sponsored by the Consortium for Materials Development in Space at the University of Alabama-Huntsville and developed by Space Hardware Optimization Technology Inc., Floyd Knobs, IN, was designed to foster separation capabilities for terrestrial commercial application and microgravity research. This particular mission focused on understanding gravitational effects on the manufacture of recombinant hemoglobin products. This area may have significant impact on blood transfusion products where transfusion of hemoglobin rather than whole blood can reduce complications such as blood rejection, infectious disease transmission and blood contamination in areas without suitable storage capability.

The Commercial Generic Bioprocessing Apparatus (CGBA) housed a number of small test tube-sized fluid mixing syringes controlled at several different temperatures. The versatility of this apparatus allowed investigations on a variety of molecular, cellular, tissue and small animal and plant systems. Sponsored by BioServe Space Technologies, a number of specific commercial objectives were pursued in partnership with several industrial affiliates. These included evaluation of pharmaceutical production of bacterial and fungal systems with Bristol-Myers Squibb, crystallization of oligonucleotides-RNA to gain 3-D structural information for drug design in AIDS research with NeXstar and Amgen, administration of a proprietary chemical to enhance bone marrow macrophage differentiation with Chiron Corp., and tests of proprietary cell growth inhibitors (cancer research) with Synchrocell, Lockheed Martin and the Kansas State University Research Foundation.

The Plant Generic Bioprocessing Apparatus (PGBA) was developed by BioServe Space Technologies in collaboration with the Wisconsin Center for Automation and Robotics at the University of Wisconsin-Madison. In collaboration with Bristol-Myers Sqibb, the commercial goal was to investigate the change in the production of secondary metabolites in microgravity.

The Fluids Generic Bioprocessing Apparatus-2 (FGBA-2) payload represented an evolutionary step in carbonated fluids management technology. For the Coca-Cola Co., the primary corporate sponsor, FGBA-2 provided a test bed to determine if carbonated beverages can be produced from separately stored carbon dioxide, water and flavored syrups and determine if the resulting fluids can be made available for consumption without bubble nucleation and resulting foam formation. Coca-Cola also verified and obtained additional data on the effects of space flight on changes in taste perception. Such data might aid in understanding altered tastes in specific target populations on Earth, such as the elderly, and eventually lead to altered beverage formulations that could increase hydration for such individuals and for astronauts.

IMMUNE-3 experiments goal was to test the ability of Insulin-like Growth Factor to prevent or reduce the detrimental effects of space flight on the immune and skeletal systems of rats. The acquired knowledge could be used to develop protocols designed to protect the immune systems of patients undergoing chemotherapy or radiotherapy, to treat patients with AIDS, primary immuno-deficiency and a broad range of infectious diseases. The experiment was sponsored by

BioServe Space Technologies and Kansas State University, Manhattan. The corporate affiliate leading the IMMUNE-3 investigation was Chiron Corp., Emeryville, CA. NASA's Ames Research Center, Mountain View, CA, provided payload and mission integration support.

Three Commercial Protein Crystal Growth investigations on this flight used three techniques. One was a process driven by temperature change that produced crystals of a new form of recombinant human insulin provided by Eli Lilly; the other used vapor diffusion to crystallize different proteins with objectives that address a range of diseases. The insulin crystals support a better understanding of the protein's structure to help Eli Lilly, an affiliate of the Center for Macromolecular Crystallography, evaluate the mode of action of this new form of insulin. The microgravity environment helps to produce large, well-ordered protein crystals. Knowledge of these structures can facilitate the development of new or more effective drugs to combat diseases.

The Gas Permeable Polymer Membrane (GPPM) experiment used microgravity for development of enhanced polymers for manufacture of improved rigid gas permeable contact lenses. Polymer development of lens material in microgravity has shown polymers can be formed that have greater uniformity of structure, increased gas permeability allowing greater oxygen flow for improved comfort to wearers, greater durability of material and greater machinability in the manufacturing process. NASA's Langley Research Center, Hampton, VA, and Paragon Vision Sciences of Phoenix, AZ, were the partners in this commercial research effort.

The Commercial Float Zone Furnace (CFZF) experiments had the goal of producing large, ultra-pure compound semiconductor and mixed oxide crystals for electronic devices and infrared detectors. Three international agencies cooperated on the project: NASA Marshall Space Flight Center, Huntsville, AL, the Canadian Space Agency (CSA) and the German Space Agency (DARA). The U.S. samples of gallium arsenide (GaAs) and gallium antinomide (GaSb) were prepared by the University of Florida in cooperation with industrial participant Atramet, Inc. The parabolic-ellipsoid mirror type furnace was provided by the CSA and DARA.

The Space Experiment Facility (SEF), developed and managed by The University of Alabama in Huntsville's Consortium for Materials Development in Space, housed a crystal growth experiment and a metals experiment. The crystal growth experiment, which used the SEF's transparent furnace, focused on mercurous chloride, a valuable electro-optic material of commercial interest. Larger and higher quality mercurous chloride crystals could improve devices used in spectral imaging.

The metals experiment, conducted in SEF's opaque furnace, used liquid phase sintering (LPS) to bond powdered metals. LPS provides greater understanding of alloy behavior and porosity on these metal composites. One area that could potentially benefit from improved metal composites is the machine tool industry.

The NIH-C7 experiment continued the collaboration between NASA and the National Institutes of Health (NIH). It was a middeck-locker experiment that investigated the effect of space flight on musculoskeletal development at the cellular level. The experiment used a computerized tissue culture incubator known as the Space Tissue Loss Culture Module to study the effects of space flight on muscle and bone cells from chicken embryos. Results of this research may lead to development of measures to maintain the strength of muscles and bones during long-duration space voyages and provide insights and health benefits for people on Earth as well. The module was developed at the Walter Reed Army Institute of Research, Washington, DC, to study cells in microgravity.

The Global Positioning System (GPS) Attitude and Navigation Experiment (GANE), sponsored by Johnson Space Flight Center (JSC), Houston, TX, is a Department of Defense navigation system that allows world-wide navigation capabilities. GPS allows anyone anywhere to know their position within 100 meters or less. Just about anyone, including pilots, boaters and hikers, can use this system for accurate real-time position and velocity determination. The International Space Station will use GPS not only for position, velocity and time information, but attitude determination as well.

The Vented Tank Resupply Experiment (VTRE) primarily tested technologies for using a vented fill resupply method in space. In a vented fill, vapor is allowed to vent from the tank to make room for the incoming liquid. This is a common method as familiar as pouring coffee into a cup or gasoline into a gas tank. In space, however, the near total absence of gravity complicates the process. The results of the experiment could be used in future designs of spacecraft liquid storage tanks. The VTRE was sponsored by NASA Lewis Research Center, Cleveland, OH.

The Liquid Metal Thermal Experiment (LMTE) evaluated the performance of liquid metal heat pipes in microgravity conditions. Heat pipes are thermal management devices used on many existing and planned space systems for the purpose of waste heat removal. The data obtained from LMTE is invaluable to space system designers requiring high temperature heat rejection. LMTE was sponsored by the Air Force Phillips Laboratory, Albuquerque, NM, with support from the Air Force Space Test Program.

The Brilliant Eyes Ten Kelvin Sorption Cryocooler Experiment (BETSCE) was a microgravity experiment carrying an instrument that can quickly cool infrared and other sensors to near absolute zero. It was developed at NASA's Jet Propulsion Laboratory (JPL), Pasadena, CA. BETSCE was a space shuttle technology demonstration experiment to show that cryocoolers of this type, called "sorption coolers," can operate in the absence of gravity. Sorption coolers have essentially no vibration, are very efficient at these cold temperatures, and can operate reliably for more than 10 years. BETSCE experiment development was funded by the Air Force Space and Missiles System Center and the Department of Defense's Ballistic Missile Defense Organization (BMDO). NASA's Office of Space Access and Technology (OSAT) sponsored the shuttle flight for BETSCE.

Biological Research In a Canister (BRIC) 07 was the subject of research for NASA at the University of Arizona, Tucson, AZ. Space flight has been shown to affect the endocrine system of crewmembers. This study aided in the discovery of the mechanism(s) behind one endocrine system in insects which aids in research on endocrine systems in general, including human systems. BRIC experiments are sponsored by NASA's Office of Life and Microgravity Sciences and Applications.

The Gamma-ray Astrophysics Mission (GAMCIT) payload studied an enigmatic source of cosmic radiation known as gamma ray bursts. While these intense bursts of high-energy radiation were first discovered in the late 1960s by satellites watching for clandestine nuclear tests, their precise nature and origin still remain an intriguing astrophysical mystery.

The Canadian Space Agency (CSA) flew experiments in two GAS canisters, **Nanocrystal Get Away Special (NANO-GAS)** and **Atlantic Canada Thin Organic Semiconductors (ACTORS).** The results of these experiments may lead to the development of new materials with applications in high performance lasers and in electronic equipment and components.

Tank Pressure Control Experiment/Reduced Fill Level (TPCE/RFL): An important issue in microgravity fluid management is controlling pressure in on-orbit storage tanks for cryogenic propellants and life support fluids, particularly liquid hydrogen, oxygen and nitrogen. The purpose of this experiment was to provide some of the data required to develop the technology for pressure control of cryogenic tankage.

CREW BIOGRAPHIES

Commander: John H. Casper (Colonel, USAF). Casper, 52, was born in Greenville, SC, but considers Gainesville, GA, to be his hometown. He graduated from Chamblee High School, Chamblee, Georgia, in 1961; received a bachelor's of science degree in engineering science from the U.S. Air Force Academy in 1966, and a master's of science degree in astronautics from Purdue University in 1967. He also is a 1986 graduate of the Air Force Air War College.

Casper was selected by NASA in May 1984 and became an astronaut in June 1985. A veteran of four space flights, STS-36 in 1990, STS-54 in 1993, STS-62 in 1994 and STS-77, Casper has logged more than 825 hours in space.

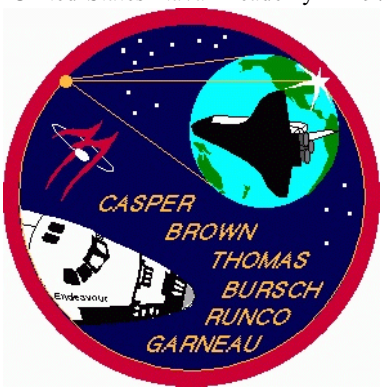
Pilot: Curtis L. Brown, Jr. (Lt. Col., USAF). Brown, 40, was born in Elizabethtown, NC. He graduated from East Bladen High School, Elizabethtown, NC, in 1974 and received a bachelor's of science degree in electrical engineering from the Air Force Academy in 1978.

Brown was selected as an astronaut candidate by NASA in June 1987 and completed a one-year training and evaluation program in August 1988 which qualified him for assignment as a pilot on future space shuttle flight crews. A veteran of three space flights, Brown has now logged more than 693 hours in space. He was the pilot on STS-47 in 1992, STS-66 in 1994 and STS-77.

Mission Specialist: Andrew S. W. Thomas (Ph.D.). Thomas, 45, was born in Adelaide, South Australia. He received a bachelor's of engineering degree in mechanical engineering, with First Class Honors from the University of Adelaide, South Australia, in 1973 and a doctorate in mechanical engineering from the University of Adelaide, South Australia, in 1978.

Thomas was selected by NASA in March 1992 and reported to the Johnson Space Center in August 1992. In August 1993, following one year of training, he was appointed a member of the astronaut corps and qualified for assignment as a mission specialist on space shuttle flight crews. With the completion of STS-77, Thomas has logged more than 240 hours in space.

Mission Specialist: Daniel W. Bursch (Cmdr, USN). Bursch, 41, was born in Bristol, PA, but considers Vestal, NY, to be his hometown. He graduated from Vestal Senior High School, Vestal, NY, in 1975; received a bachelor of science degree in physics from the United States Naval Academy in 1979,



and a master of science degree in engineering science from the Naval Postgraduate School in 1991.

Bursch was selected by NASA in January 1990 and became an astronaut in July 1991. A veteran of three space flights, Bursch has logged more than 745 hours in space. He served as a mission specialist on STS-51 in 1993, STS-68 in 1994 and STS-77.

Mission Specialist: Mario Runco, Jr. Runco, 44, was born in Bronx, NY, but considers Yonkers, NY, to be his hometown. He graduated from Cardinal Hayes High School, Bronx, NY, in 1970; received a bachelor's of science degree in meteorology and physical oceanography from the City College of New York in 1974, and a master's of science degree in meteorology from Rutgers University, New Brunswick, NJ, in 1976.

Runco was selected by NASA as an astronaut candidate in June 1987 and qualified for assignment as an astronaut mission specialist in August of 1988. A veteran of three space flights, STS-44 in 1991, STS-54 in

Inflight portrait: Left to Right, front, Andrew Thomas, John Casper and Mario Runco. Back Row, Curtis Brown, Marc Garneau and Daniel Bursch.

STS-77 Quick Look

Launch Date: May 19, 1996
Time: 5:30 a.m. CST
Site: KSC Pad 39B

Orbiter: *Endeavour*
OV-105-11th flight
Orbit/In.: 153 naut. miles
39 degrees

Mission Duration: 10 days, 39 mns,
Landing Date: May 29, 1996
Time: 6:09 a.m. CST
Site: Kennedy Space Center

Crew: John Casper, (CDR)
Curt Brown, (PLT)
Andrew thomas, (MS1)
Dan Bursch, (MS2)
Mario Runco, (MS3)
Marc Garneau, (MS4)

Cargo Bay Payloads: SPACEHAB-4
BETSCE
Spartan-207/IAE
TEAMS-01

In-Cabin Payloads: ARF-1
BRIC-07

1993 and STS-77, Runco has now logged more than 550 hours in space.

Mission Specialist: Marc Garneau (Ph.D., CSA). Garneau, 47, was born in Quebec City, Canada. He attended primary and secondary schools in Quebec City & Saint-Jean, Quebec, and in London, England. He received a bachelor's of science degree in engineering physics from the Royal Military College of Kingston in 1970, and a doctorate in electrical engineering from the Imperial College of Science and Technology, London, England, in 1973. Garneau attended the Canadian Forces Command and Staff College of Toronto in 1982-83.

Garneau was one of six Canadian astronauts selected in December 1983 and flew as a payload specialist on STS-41-G in October 1984. In July 1992 Garneau was selected for astronaut candidate training and, following one year of training, he was appointed a member of the astronaut corps and qualified for assignment as a mission specialist on space shuttle flight crews. Garneau has logged more than 437 hours in space.

The crew patch displays the Shuttle *Endeavour* in the lower left and its reflection within the tripod and concave parabolic mirror of the SPARTAN Inflatable Antenna Experiment (IAE). The center leg of the tripod also delineates the top of the Spacehab's shape, the rest of which is outlined in gold just inside the red perimeter. Also depicted within the confines of the IAE mirror are the mission's rendezvous operations with the PAM/STU satellite and a reflection of Earth. PAM/STU appears as a bright six-pointed star-like reflection of the sun on the edge of the mirror with *Endeavour* in position to track it. The sunglint on the mirror's edge is located over Goddard Space Flight Center, the development facility for the SPARTAN/IAE and TEAMS experiments. The reflection of Earth is oriented to show the individual countries of the crew as well as the ocean which Captain Cook explored in the original *Endeavour.* The mission number "77" is featured as twin stylized chevrons and an orbiting satellite as adapted from NASA's logo. The stars at the top are arranged as seen in the northern sky in the vicinity of the constellation Ursa Minor. The field of 11 stars represents both the TEAMS cluster of experiments and the 11th flight of Endeavour. The constellation at the right shows the four stars of the Southern Cross for the fourth flight of Spacehab.

Pic 1: 77705016- The Inflatable Antenna Experiment nears completion of its inflation process over California's Pacific Coast near Santa Barbara and Point Conception.

Pic 2: 77372020-Astronaut Mario Runco uses a large format camera during station keeping operations with the PAMS/STU satellite.

Pic 3: 77392007-Canadian Astronaut Marc Garneau joins Pilot Curtis Brown in checking out the audio control system for Spacehab.

Pic 4: 77365010-Astronaut Daniel Bursch works out on the bicycle ergometer.

Pic 5: 77314011-Inflight portrait: Left to Right, front, Andrew Thomas, John Casper and Mario Runco. Back Row, Curtis Brown, Marc Garneau and Daniel Bursch.